CHAPTER 4

WATER QUALITY STANDARDS

WATER QUALITY

Potable water must be free of anything that would degrade human performance. Also, it should not damage the materials used in its transportation and storage. Potable water must be suitable for maintaining human health (personal hygiene, medical treatment, and field feeding). Water quality standards give a basis for selecting or rejecting water intended for human use. These standards provide minimum accepted values for safeguarding human health.

Hydrologic Cycle

The hydrologic cycle is the term used to describe the natural circulation of raw water in, on, and above the earth. Water occurs in many forms as it moves through this cycle. The steps in the hydrologic cycle include precipitation, evaporation, infiltration, transpiration, and runoff. Water is placed in the air by evaporation from water and land surfaces and by transpiration from plants. It then condenses to produce cloud formations and returns to earth as rain, snow, sleet, or hail. Some of this evaporates, while some flows as runoff into lakes and streams. The remainder goes into the soil and then into underlying rock formations by seepage or infiltration. The water which has seeped through the earth will finally find its way to the surface through springs. It can also flow through porous media until intercepted by streams, lakes, or oceans. The cycle does not always progress through a regular sequence; steps may be omitted or repeated at any point. For example, precipitation in hot climate may be almost wholly evaporated and returned to the atmosphere.

Impurities in Water

As water goes through the hydrologic cycle, it gathers many impurities. Dust, smoke, and gases fill the air and can contaminate rain, snow, hail, and sleet. As

runoff, water picks up silt, chemicals, and disease organisms. As it enters the earth through seepage and infiltration, some of the suspended impurities may be filtered out. However, other minerals and chemicals are dissolved and carried along. As ground water in underground deposits, it may contain disease organisms as well as harmful chemicals. In addition to the impurities in water resulting from infiltration, many are contributed by an industrialized society. Garbage, sewage, industrial waste, pesticides, and NBC agents are all possible contaminants of raw water. Impurities in raw water are either suspended or dissolved. Suspended impurities include diseases organisms, silt, bacteria, and algae. They must be removed or destroyed before the water is consumed by soldiers. Dissolved impurities include salts, (calcium, magnesium, and sodium), iron, manganese, and gases (oxygen, carbon dioxide, hydrogen sulfide, and nitrogen). These impurities must be reduced to levels acceptable for human consumption.

RAW WATER CLASSIFICATIONS

Water is classified as fresh, brackish, or salt water (seawater) based on the concentration of TDS. Fresh water has a TDS concentration of less that 1,500 ppm. Brackish water is high in minerals and has a TDS concentration between 1,500 ppm and 16,000 ppm. Salt water has a TDS concentration greater than 15,000 ppm.

Generally, ground water (subsurface) has less chemical or biological contaminants than surface water, provided reasonable care is exercised in the selection of the well site. Harmful microorganisms are usually reduced to tolerable levels by passage through the soil.

TREATED WATER CLASSIFICATIONS

Treated water may be classified as potable and palatable. These classifications are discussed below.

Potable Water

Potable water is water that has been treated and disinfected so that it is free from disease-producing organisms, poisonous substances, chemical or biological agents, and radioactive contaminants which make it unfit for human consumption or other uses. It is water that has been approved by the command surgeon or his representative for soldier issue and consumption.

Palatable Water

Palatable water is water that is pleasing in appearance and taste. It is significantly free from color, turbidity, taste, and odor. It should also be cool and aerated. Water may be palatable and at the same time not be potable.

POTABLE WATER QUALITY STANDARDS

Water for soldiers will be of the highest quality possible. Quality standards for treated water reflect the values of substances allowed in potable water. Standards exist to measure the physical, chemical, microbiologic, and radiologic quality of water and to test for the presence of chemical agents.

Physical Quality

The principal physical characteristics of water are color, odor and taste, turbidity, and temperature. These characteristics and their related quality standards are described below.

Color. Color in water comes from colored substances, such as vegetable matter, dissolved from roots and leaves, from humus, or from inorganic compounds such as iron and manganese salts. The color standard is designed to make drinking water more palatable.

Odor and taste. There are no set standards for odor and taste as there are no specific tests for these. Odor and taste found in water are most commonly caused by algae, decomposed organic matter, dissolved gases, or industrial waste. Remove tastes and odors which make water unpalatable.

Turbidity. Turbidity refers to a muddy or unclear condition of water caused by suspended clay, silt, organic and inorganic matter, and plankton and other microorganisms. The turbidity standard was established to improve the efficiency of disinfection by reducing particles to which microorganisms could attach.

Temperature. Warm water tastes flat. Cooling water suppresses odors and tastes and makes it more palatable. Temperature also effects the chlorination and purification of water. Disinfection takes longer

when water is colder, and purification capacity is reduced with reverse osmosis treatment equipment.

Water having physical characteristics exceeding the limits or making it less palatable should not, as a general rule, be used for drinking. Otherwise, reduced consumption and increased risk of dehydration may result. When water of low physical quality must be used, the appropriate command level will make that decision based on medical recommendations.

Chemical Quality

The chemical quality of water depends on the chemical substances it contains. These substances include TDS, chlorides, sulfates, and other ions. The chemical quality of water involves its hardness, alkalinity, acidity, and corrosiveness. Chemical substances having an adverse health effect have established standards that will not be exceeded without medical approval.

Potential hydrogen. The pH is a measure of the acidic or alkaline nature of water. It is technically defined as the negative logarithm of the hydrogen in concentration. It ranges from 0 to 14. A pH of 7 is neutral. The pH influences the corrosiveness of the water, the amount of chemicals needed for proper disinfection, and the ability of an analyst to detect contaminants. Water with a pH below 7 is regarded as acidic while that with a pH above 7 is regarded as alkaline. The pH standard was established to ensure effective purification and disinfection.

Arsenic. Arsenic can be present in natural water sources in a wide range of concentrations. It can come from either natural or industrial sources. Ingestion of low concentrations of arsenic can cause nausea, vomiting, abdominal pain, or nerve damage. In high enough doses it can kill. The standard for arsenic was established to ensure that no adverse health effects would occur to degrade soldier performance.

Chloride. Chloride exists in most natural waters. It is the main anion found in seawater. Chloride comes from natural salt deposits, domestic and industrial waste, and agricultural runoff. Even in low concentrations, chloride can produce an objectionable taste in water. The chloride standard ensures that potable water is also palatable. This will reduce the chance that soldiers will reject the water and suffer from dehydration or heat injury.

Cyanide. Cyanide can be present in natural water. It can come from industrial sources, such as metal processing, coke production, mining, or photograph development. Chlorination of water containing hydrogen cyanide results in the formation of cyanogen chloride, a toxic chemical agent. Ingestion of low concentrations of cyanide can cause headaches, nausea, or nerve tremors. In high doses, cyanide can result in convulsions, paralysis, respiratory arrest, or death. The standard for cyanide was established to ensure that no adverse health effects would occur to degrade soldier performance.

Lindane. Lindane is a widely used agricultural insecticide. It enters water sources from aerial spraying, runoff, or direct application for mosquito control. Wells may be contaminated with lindane when the chemical is spilled around the well during mixing operations or from prolonged exposure to repeated applications in surrounding areas. When ingested in small doses lindane can cause dizziness, headaches, nausea, vomiting, or tremors. At higher doses, severe seizures, respiratory failure, cardiovascular collapse, or death may occur. The standard for lindane was established to prevent toxic effects which would degrade soldier performance.

Magnesium. Magnesium is the eighth most abundant element on earth. It is a principal cation contributing to water hardness. When ingested in moderate doses, magnesium acts as a laxative. The magnesium standard was established to prevent chemically induced diarrhea, which could interfere with soldier performance.

Sulfates. Sulfates occur naturally in water as the result of dissolution of sulfur-bearing minerals. Significant concentrations also result from industry sources, such as coal mine drainage, pulp paper mills, tanneries, textile mills, and domestic waste water. When ingested, sulfates have a laxative effect. They also can produce a bad taste in water. The sulfate standard was established to prevent chemically induced diarrhea, which could interfere with soldier performance.

Hardness. Hardness, a characteristic of water, is chiefly due to the carbonates and sulfates of calcium,

iron, and magnesium. It is commonly computed from the amounts of calcium and magnesium in the water and expressed as equivalent calcium carbonate.

Total dissolved solids. The TDS of water is composed of mineral salts and small amounts of other inorganic and organic substances. The proportion of each constituent is the result of weathering of rocks found in the drainage basin and of any industrial contributions. Since TDS is composed of chloride, magnesium, sulfate, and other ions, its ingestion in water has the same effects. Therefore, the TDS standard was established to prevent chemically induced diarrhea, which could interfere with soldier performance.

Chemical water quality standards are based on the effect the water will have on the health of the soldier. The effect of a particular chemical substance determines if a limit is established for that substance. Chemical substances having a negative physical effect will have a mandatory limit that should not be exceeded. Some substances, such as iron and manganese, have no significant negative physical effect, but may restrict the use of the water, such as for the laundering of clothes.

Microbiological Quality

The microbiological quality of potable water shows its potential for transmitting waterborne diseases. These diseases may be caused by viruses, bacteria, protozoa, or higher organisms. A microbiological test will reveal the quality of the raw water source and aid in determining any treatment required. The test is necessary to maintain the quality of the water. The testing for microorganisms in water is extremely difficult. The number of these organisms is usually very low, even in a badly polluted water supply, and the test used to find them is difficult. For these reasons, indicator organisms are used to detect the presence of contamination. The bacterial organisms used as an indicator of possible contamination are total coliform. These organisms occur in large quantities in the intestines of warm-blooded animals. The presence of any coliform organism in treated potable water is an indication of either inadequate treatment or the introduction of undesirable materials to the water after treatment. While the detection of many disease-causing microbes is difficult, the test to detect a surrogate organism, E. coli, is simple and effective for field use. Because of its relative simplicity and field adaptability, the membrane filter technique has gained wide acceptance throughout the military as the preferred technique for the presumptive determination of the presence of coliform organisms in potable water. This test is conducted by Preventive Medicine Specialists working on behalf of the Division, Corps, or Theater Surgeon. The microbiological standard was established to ensure infectious microorganisms would not cause diseases in soldiers.

Radiological Quality

Radioactive elements may appear in water supplies as a result of naturally occurring contamination. Radioactive elements may also enter water from indiscriminate disposal of hospital or industrial nuclear waste as well as a result of leakage from reactors. These are all in addition to the deliberate effect of nuclear weapons directed at soldiers engaged in combat on the active NBC battlefield.

Chemical Agent Standards

Chemical agents have been used recently in Afghanistan, Southwest Asia, and in the Iran-Iraq War. Their purpose is to incapacitate or kill enemy soldiers and allow friendly forces to seize the initiative. All chemical agent standards were established to prevent degradation of soldier performance by low levels of agents. The M272 Water Testing Kit-Chemical Agents is used to detect the following chemical agents.

Hydrogen cyanide. This agent interferes with enzymes which facilitate the use of oxygen by cells. Its effects in small or large doses are the same as those for cyanide.

Lewisite. The active ingredient in Lewisite is arsenic. Arsenic disrupts the digestive, circulatory, and nervous systems.

Mustard. This agent causes skin blistering and blindness. If ingested, it can cause vomiting and fever as it burns the lining of the stomach and intestines.

Nerve agents. These agents attack the enzymes which control the nervous system. They cause

drooling, difficulty in breathing, nausea, vomiting, and involuntary defecation. In large doses, they can cause convulsions, respiratory failure, or death.

Radiological Standards

Radiological water quality standards are based on the fact that radiation has an adverse physical effect on soldiers. Any treated water that contains nuclear contamination should be avoided. When ingested, radioactive isotopes interfere with the reproduction of human cells. They cause nausea, vomiting, and hair loss and weaken the body's defenses to infections. Current water treatment methods are able to provide potable water of the desired radiological quality. Water purification operators and preventive medicine personnel are responsible for measuring levels of radioactivity in water supplies.

DEVELOPMENT OF STANDARDS

Field water quality standards have been developed by international agreements among the NATO and Quadripartite forces. These organizations have agreed, when operating on land, to adopt minimum requirements for potability of drinking water to be issued to soldiers in combat zones or in any other strict emergency situations. STANAG 2136 provides guidance on short term (1 to 7 days) standards under these conditions while QSTAG 245 provides guidance on both short-term and long-term (greater than 7 days) standards. STANAG 2885 provides guidance on the development, treatment, acceptability, and provision of water in the field. QSTAG 479 specifies minimum requirements for conducting water quality analyses. As a member of both organizations, the US has agreed to accept and provide water meeting these standards when participating in mutual logistical water support under field conditions (see Appendix C, Tables C-1 through C-4).

Water quality standards for the usc of potable water in the field are based on the length of time the water is to be consumed. Some of these standards were also developed to set limits for the palatability of water.

Emergency situations. No standards apply when soldiers are cut off from supply lines and treated water is not available from QM supplies. Each soldier should select the clearest, cleanest water with the least odor and then treat the water using individual water purification procedures. Such procedures are limited to disinfection using iodine tablets, chlorine ampules, or boiling (FM 21-10, Chapter 2, Section IV).

Short-term consumption. The short-term standards in Appendix C, Table C-2, apply to units operating for 7 consecutive days or less when the commander, upon medical advice, determines that a field operational condition exists which prevents soldiers access to potable water meeting long-term consumption standards. The commander must accept potential soldier performance degradation, increased incidence of disease, casualties from toxic substances, and reduced combat efficiency with each day the standards remains in effect. These units would rely on water treatment by man-portable water purification devices, if available, or by individual water purification procedures. Untreated water sources should be tested for compliance with the standards. Unit personnel should use the M272 Water Testing Kit if chemical warfare is suspected in their operating area.

Long-term consumption. The long-term standards in Appendix C, Table C-3, apply to all situations of more than 7 days where treated water is produced by water purification units.

The classifilcations of water use in Appendix C, Table C-4, are set to protect soldiers from contracting diseases from water that comes in contact with their skin or that is incidentally inhaled or ingested in small amounts. These classifications are also designed to protect equipment and clothing from deterioration. Water of the next higher quality may be used for any of the purposes listed in Table C-4 when water conservation considerations permit. Water of the next lower quality will not be used unless an emergency exists. The command surgeon will recommend the use of lower quality water. In areas where diseases transmitted through skin contact with water are present, only potable water will be used for showering, bathing, or other bodily contact.

DISEASES AND DISINFECTION

Potable water supplies will be disinfected because no other treatment processor combination of processes will reliably remove disease-producing organisms from water. The unit commander will instruct soldiers not to drink unapproved water which could cause disease. The nature of waterborne diseases and disinfection methods are discussed below.

Waterborne Diseases

Water is a carrier of many organisms which cause intestinal disease. An epidemic of one of these diseases among Army soldiers can be more devastating than enemy action and can cause great damage to morale. A heavy responsibility thus rests upon water purification personnel and the unit field sanitation team to maintain proper disinfectant residuals. The water treatment methods to be used when certain chlorine-resistant organisms are found should be prescribed by the command surgeon who can recognize or anticipate the presence of these organisms. The command surgeon will recommend such additional chlorination or other treatment as may be necessary. A waterborne disease rarely produces immediate symptoms in its victims. An incubation period must pass before the victim comes down with the disease. During this period, the disease organisms are growing and multiplying in the host. Therefore, an absence of symptoms for several days after drinking untreated water is no guarantee that the water is safe. The absence of disease among the local inhabitants is also no assurance of safety because they may have developed immunity.

Disinfection

Chlorination will be used for disinfection of potable water in all cases with the exception of individual or small unit water purification for which iodine tablets may be used. The efficiency of chlorine disinfection is affected by the following:

- The form of chlorine present, the pH of the water, and the contact time. As the pH of the water increases from 5 to 9, the form of the chlorine residual changes from hypochlorous acid (HOC1) the most effective form to hypochlorite ion (OC1) which is less effective. The most effective disinfection occurs when the pH is between 5.5 and 6.5. At the same pH, a longer contact time also results in increased disinfection.

- The type and density of organisms present (virus, bacteria, protozoa, helminth, or others) and their resistance to chlorine. Bacteria are the most susceptible to chlorine disinfection while the cysts of the protozoa Entamoeba histolytica and Giardia lamblia are the most resistant.

- The concentration of substances other than disease-producing organisms that exert a chlorine demand. During disinfection, chlorine demand can be exerted by chemical compounds such as those containing ammonia and organic material. Many of these compounds are not effectively removed in conventional water treatment processes and may be present to exert chlorine demand during disinfection.

- Adequate mixing of chlorine and chlorine demanding substances. The disinfecting agent must be well dispersed and thoroughly mixed to ensure that all of the disease-producing organisms come in contact with the chlorine for the required contact time.

Under normal operating conditions, water purification personnel will add sufficient chlorine to treated water to produce a chlorine residual of at least 5.0 ppm after 30 minutes contact time at a pH between 6.5 and 7.5. If chlorine supplies are low and there is a need to conserve remaining supplies, the command surgeon may authorize reduced chlorine residuals. Disease-producing organisms such as Entamoeba histolytica and Giardia lamblia are resistant to normal chlorine residuals. In areas where they are widespread, the command surgeon may require higher than normal residuals and longer contact times.